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Assessment of climate change adaptation measures on the income of herders in a pastoral region

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ABSTRACT

Climate change, characterized with global warming, created severe potential threat to natural ecosystems and sustainable development of human society. Effective adaptation measures to mitigate the negative effects of climate change would affect both the ecological environment and the social economy. In this paper, we built a positive mathematical programming model to assess adaptation measures, which were divided into four aspects, to tackle climate change based on the survey data obtained from seven counties and 32 villages in the region of Hulun Buir. The results showed that, livestock breeding improvement had a positive impact on grass yield, livestock number and especially herder's household income (the most in Ewenki (11.7%) and the least in Xinzuo (2.3%)); artificial grassland project could lead to an average growth rate of 8.4% in household income among the four counties; current policies and going out for work could also increase household income, however, not a sustainable choice. To realize sustainable development in the context of global climate change, the vitality of sustainable development of animal husbandry under the premise of protecting ecological environment should be enhanced. For example, improving the safety and quality of livestock products through influencing livestock breeding, processing technology and high quality forage, and ensuring adequate forage supplement through artificial grassland project.

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1. Introduction

In recent years, climate change has brought severe challenges for natural ecosystems and sustainable development of human society. Greenhouse Gases (GHG) produced by significant energy consumption during global industrialization is considered to be the main force of climate change (Zhang and Choi, 2013; Long et al., 2015; Anderson et al., 2016). Without any prevention measures, current speed of climate change is considered to be beyond the limits of adaptation in many countries all around the world (Liu et al., 2015). Under these conditions, natural ecosystems are undergoing noticeable and rapid change (de Oliveira, 2013; Fang and Wei, 2013), reflected as sea level rising, increasing frequency of extreme weather disasters and changing in atmospheric precipitation patterns (Kivyiro and Arminen, 2014; Kasman and Duman, 2015; Luo et al., 2017), especially in ecologically fragile areas (Fang et al., 2011; Liu et al., 2013). The changes to natural ecosystems will have a profound impact on social economic systems inevitably (Wang et al., 2011; Stern, 2013; Zhan et al., 2017).

Under this circumstance, climate change has become an important issue that countries all around the world must pay attention to. The approaches to cope with climate change mainly including two aspects. On the one hand, governments around the world are trying to tackle with climate change by reducing GHG, especially carbon emissions (Hamit-Haggar, 2012; Shahbaz et al., 2013; Ozturk and Acaravci, 2013; Deng et al., 2016), such as the Copenhagen Conference in 2009 and the United Nations climate change conference in 2015. On the other hand, researches have been conducted into adaptive management and adaptation mechanisms to improve the adaptability of social-economic systems, reduce vulnerability and realize the sustainable development of national social economies (Van Aalst et al., 2008; Blanco et al., 2017). This approach is especially important in ecologically fragile areas (Stringer et al., 2009). China is such a country with the largest ecologically fragile areas among the world (Orioli et al., 2015; Pan and Dong, 2016), and in these regions, the majority of people

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suffer from poverty and the complex ecological problems caused by climate changes, which directly affect people's lives (Tologbonse et al., 2011; Deng et al., 2013). Therefore, it is of great significance to study the adaptive management of ecologically fragile areas both practically and theoretically.

The concept of adaption originated from population ecology and evolutionary ecology. Although different disciplines have slightly different definitions, it is generally agreed that adaption refers to the extent to which the system adjusts according to the expected or actual environment in function or internal structure (Engle, 2011). Adaptive capacity refers to the ability that systems, institutions, human societies and other organisms (environmental changes) have to adapt to potential damage, to make use of opportunities or to deal with consequences (Goklany, 2007). Adaptive management addresses the question that how to adapt. It is generally believed that adaptive management is a structural, interactive and moderate decision-making method proposed in the face of system uncertainty, which could reduce the uncertainty of decision-making through long-term observation of the system. The concept of adaptive management was first proposed by Holling (1979) for the management of ecosystem uncertainty, complexity and time-lags. In recent years, adaptive management has been introduced into the field of climate change responses and the adaptation measures which can be explained as the patterns implemented by both governments and herders to circumvent or weaken the impact of climate change on the socio-economic system (Davoudi et al., 2012; Liu et al., 2013; Wang et al., 2018).

Adaptive management strategies can be divided into spontaneous adaptation and anthropogenic adaptation of natural ecosystems according to the objectives. Anthropogenic adaptation can be further divided into ecosystem adaptation and human adaptation. In terms of ecosystem adaptation management, international organizations and agencies such as World Wide Fund for Nature or World Wildlife Fund, International Institute for Applied Systems Analysis have used adaptive management to implement a series of eco-environmental conservation and management plans. Examples include Wild Species and Fish Conservation Programs in the Mississippi Valley, the Ecological Restoration Project in the Missouri Valley (Prato, 2003), and the Water Quality Improvement Project of Great Barrier Reef, Australia (Broderick, 2008), which have all been well applied and promoted. Ramalingam et al. (2014) proposed a set of best practices for adaptation published in the *Open Standards for the Implementation of Conservation*. In terms of human adaptive management, the Development Strategy Report issued by The World Bank and the United Nations Development Program listed adaptive governance structure and institutional reform as priority actions. Adaptive management was applied to the International Sustainable Development Planning (Smith and Young, 2009; Allen et al., 2015). In the Global Adaptive Management Program, the Collaborating, Learning and Adapting method was also developed (Fritz et al., 2014).

As one of the most effective approaches to tackle climate change, especially in ecologically fragile areas, it has aroused increasing number of scholars' attention, but the existing researches about adaptation to climate change mostly focused on "how to adapt", like Deng et al. (2010), Wise et al. (2014), Barreca et al. (2015), but rarely studies analyzed the potential impact or assessed the effect of adaptation measures which were the key point to provide decision support for effective adaptive management (Liu et al., 2013). Clarifying the problems existing in the implementation of adaptation measures is of great significance on adjusting adaptive strategies, improving adaptive effect and strengthening the adaptation management.

Therefore, this paper chose Hulun Buir, an ecologically fragile region in Inner Mongolia, as the study area, focusing on assessing anthropogenic adaptation measures that herders had to avoid loss from climate change, dividing the adaptation measures into four aspects based on the survey data and assessing the effect through total household income, meanwhile taking agriculture income and non-agriculture income into account. We also clarified the adaptive loss and return arising from a matrix of multiple adaptation measures, introducing the logical perspectives of mathematical empirical planning to analyze the differences that may be caused by the adaptation measures in the development of grassland animal husbandry and thus provide decision support for effective adaptive management tackling climate change in ecologically fragile areas, especially grassland regions in the world.

2. Material and methods

2.1. Study area and data

2.1.1. Study area

The Hulun Buir is located in the north part of Inner Mongolia (Fig. 1), possessing typical grassland, which is rich in resources and natural pasture. However, in recent years, 66% of all pastures have been degraded. But as the pillar industry in Hulun Buir, the animal husbandry development mainly relies on natural grasslands with large internal variations, a poor capability for resisting natural disasters and a fragile ecological environment, which resulted in the socio-economic system and the further development of animal husbandry are both very sensitive to climate change. For example, in the two harvest years of 2013 and 2014, the total precipitation in May–August was 545.4 mm and 404.6 mm respectively, and the grass yield reached a maximum of 150 kg/km^2 with an accumulated surplus of 1 million tons of hay. However, in the drought year of 2016, May–August precipitation and grass production were only 192.9 mm and 75 kg/km^2 respectively, and there was a shortfall of grass of more than 0.67 million tons. Drought is the most significant natural disaster in Hulun Buir. Recently, due to the impact of global climate change, the consequences of many natural disasters have increased in severity and frequency. Therefore, it is essential to carry out effective adaptive management for climate change to enhance the capacity for climate change adaptation in region, reduce property loss and ensure people's livelihood.

2.1.2. Data

The socio-economic data in this paper was derived from the 2016 household survey in Hulunbuir. The target objects of survey were the grassland herders. Counties located in pastoral area (including Xin Barag Right Banner (hereinafter referred to as Xinyou), Xin Barag Left Banner (Xinzuo), Prairie Chenbarhu Banner (Chen), Ewenki Autonomous Banner (Ewenki)) and semi-rural and semi-pastoral area (including Zhalan Tun (Zha), Daur Autonomous Banner of Morin Dawa (Mo) and Arun Banner (Arun) were chosen to conduct the survey. Seven banners and 32 villages were visited and 138 questionnaires were collected (Table 1).

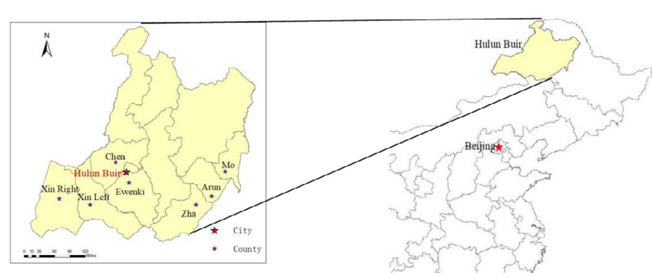

Fig. 1. Location of the study area and sampled points for questionnaire data collection.

Table 1
Summary of basic information of questionnaire data.

County	Frequency	Percentage
Xinyou	23	16.67%
Xinzuo	21	15.22%
Chen	20	14.49%
Ewenki	19	13.77%
Zha	21	15.22%
Mo	16	11.59%
Arun	18	13.04%
Total	138	

Table 3
Implementation of various adaptation measures by herders.

Adaptive measures	1 = Yes	0 = No	Sum
Forage reserve	98.2%	1.8%	98
Livestock breeding improvement	74.9%	25.1%	98
Go out for work	27.3%	72.7%	98
Cooperation round rotation	25.7%	74.3%	98
Reduce livestock	10.5%	89.5%	98
Grazing into homes feeding	1.6%	98.4%	98
Site walks	0.0%	100%	98

Source: The research data.

Through questionnaire survey, we found that drought was the most common natural disaster in Hulun Buir and caused the most severe economic loss. Forage grass was the key factor restricting the development of animal husbandry in pastoral areas. In terms of adaptability, “Reserving forage grass” was the most important measure to dealing with disasters. “Dealing livestock” was a loss-cutting measure for herders in times of inadequate forage supply and severe loss from meteorological disasters. In addition, policy is also an important approach implemented by governments tackling climate change, like ‘Returning Farmland to Forests’ and ‘Returning Farmland to Grassland’. These policies, however, only focused on protecting grassland ecology, while ignored the economic function of grassland to some extent, restricted the improvement of herder's living standards and coupled with the effect of extreme weather disasters. “Farmers' off-farm employment” has become a common choice for some herders to adapt to climate change and increase their household income.

To assess the adaptation measures to climate change better, based on the survey data, this study classified herders’ understanding of adaptation measures for meteorological disasters (Table 2) and the proportion of various adaptation measures implemented by herders at the household level (Table 3).

2.2. Methods

The positive mathematical programming (PMP) model was first proposed by Howitt. The model can be calibrated according to the observed production behavior in the base period to ensure that the optimal base period value of the model agrees with the observed value. This method is subject to base-term calibration conditions, which provides greater flexibility, and follows the basic hypothesis of diminishing marginal returns in economics. These advantages support the widespread application of the model in policy effectiveness analysis (Howitt, 2005; Petsakos and Rozakis, 2015; Cortignani and Dono, 2015). The process of the PMP model to analyze the costs and benefits of adaptation measures to climate change can be divided into the following three steps:

The first step, the calibration constraints are added in the linear programming model based on the actual observations of the base period, and the linear programming model is used to calculate the dual values of each calibration constraint (Shadow Price). Therefore, an ordinary linear programming model can be considered as the first step in the model.

The objective function:

$$T = MAX\sum(pixi - cixi) \tag{1}$$

Subject to:

$$\sum xi \le b \tag{2}$$

$$xi \le bi \tag{3}$$

$$xi \ge 0 \tag{4}$$

where, T is the net gain of adaptive measures, pi is the economic loss of the i adaptive measure reduction; ci is the cost of implementing the i adaptive measure; xi is the investment allocated to each adaptive measure; b is the total investment of adaptive measures, and bi is the i kind of adaptation measure input.

The second step, the slope of the average cost function in the objective function of the PMP model is calculated according to the dual values of the calibration constraints, and the PMP model is established. The PMP model assumes that the marginal revenue of various crops is decreasing, so the average cost in the objective function is no longer a fixed value ci, but $0.5\gamma ixi$, because the slope

Table 2
Herders’ assessment of meteorological disaster adaptation measures.

Sort	Drought	Sandstorm	Snowstorm Disaster	Snow Disaster	Pest Disaster	Extreme Temperature
1	Reserving forage (+++)	Grazing into homes feeding (+++)	Reserving forage (+++)	Reserving forage (+++)	Artificial grassland technology promotion (+++)	Reserving forage (+++)
2	Cooperation round rotation (o)	Dealing livestock (+++)	Dealing livestock (+++)	Shed circle construction (++)	Epidemic prevention (+++)	Livestock improvement (+++)
3	Drilling wells (+)	Wheel pasture (o)	Shed circle construction (++)	Accurate weather information (+)	Site walks (o)	Accurate weather information (+)
4	Forage grass (++)	Cooperation round rotation (o)	Accurate weather information (++)	Killing livestock (+++)	Buy forage (+++)	Weather knowledge training (+)
5	Dealing livestock (+++)	Livestock improvement (o)		Weather knowledge training (+)	Dealing livestock (+++)	
6	Shed circle construction (o)	Artificial grassland technology promotion (+++)				
7	Accurate weather information (+)					
8	Weather knowledge training (+)					

Note: +++: Extremely important; ++: Very important; +: important; o: general; -: unimportant.

of the average quadratic cost function is 1/2 that of the marginal cost function. The PMP model assumes that the marginal cost curve passes through the origin, that is, if the marginal cost function is in the form of $\gamma i x i$, then the average cost function is $0.5\gamma i x i$. This PMP model can be expressed as:

$$T = Max \sum \left[pi - \left(\alpha i + \frac{1}{2} \gamma i x i \right) \right] xi \tag{5}$$

where γi is the slope of the editing cost function, calculated as: $\gamma i = \frac{\lambda cal(i) + ci}{xi}$, and $\lambda cal(i)$ is the dual value of the calibration constraint calculated in the first step.

The third step, the PMP model established above is applied to change the corresponding parameters in the model to obtain the parameter αi, γi according to the needs of the specific adaptive evaluation, and take them into the objective function, so as to find the optimal solution to the nonlinear programming in which the adaptive measures are distributed.

To assess the effects of adaptation measures to climate change and the implementation of policy subsidies in pastoral areas, a model of pastoral production behavior planning was built based on survey data and the implementation effect of adaptive measures was assessed through total household income, grass yield in next year and changes in livestock number. According to the assumption of maximizing household income, it was assumed that herders would seek to maximize short-term income without obvious technological progress. Their household income mainly came from animal husbandry and non-agricultural employment. The animal husbandry income mainly came from farming production. The non-agricultural income mainly came from migrant workers and other non-farm family production and business activities. Therefore, the construction of the objective function was as follows.

The objective function:

$$TMGfarm = \max \sum (piyi - (\alpha i + \gamma i/2 \times xi))xi + subsidy \tag{6}$$

Subject to:

$$\sum xi \times li \le L \tag{7}$$

$$\sum xi \le Area \tag{8}$$

$$\sum xi \times qi \le I \tag{9}$$

$$TMGfarm \le TMGtotal \tag{10}$$

where, *TMGfarm* represents the income of herdsman breeding, *pi* represents the price of livestock, *yi* represents the number of cattle and sheep per unit of grassland, αi is the cost per *mu* of land, *xi* is the grassland area for stocking cattle and sheep, *subsidy* represents the reimbursements from the government to herders who followed the government call of returning grazing land to grassland, increasing the animal husbandry balance, and prohibiting grazing activities in conservation areas. *li* is the labor input per acre, *qi* is the capital investment per *mu* and *TMG*total is the total household income.

Since migrant workers are the main source of non-agricultural income, it is possible to replace the non-agricultural production projection with an approximate income from working outside.

The objective function:

$$TMGnonfarm = \max \sum w \times labernonfarm \tag{11}$$

Subject to:

$$labernonfarm \le L \tag{12}$$

$$TMGnonfarm \le TMGtotal \tag{13}$$

where *w* represents the net non-farm payrolls, *labernonfarm* represents the non-farm working hours that can be provided. TMG_{total} is calculated as follows:

$$TMGtotal = TMGfarm + TMGnonfarm \tag{14}$$

3. Results

In Hulun Buir, Inner Mongolia, the major adaptation measures is livestock breeding improvement, artificial grassland, policy subsidies and go out for work based on Table 2, Table 3 and survey data, which represent the impacts of adaptation measures from the perspective of technology, engineering, policy and herder's action. Among them, we assessed the effect of adaptive technology measures and engineering measures through grass yield in next year, livestock changes and income from animal husbandry (Table 4), and assessed the effect of adaptive policy measures and herders' actions through changes in household income (Table 5).

3.1. Effects of technological adaptation measures

Among technological adaptive measures, livestock breeding improvement is the main approach implemented by herders according to Table 3. The analysis of its adaptability and effects in the context of the increasing frequency of meteorological disasters from climate change is shown in Fig. 2.

Under the condition of extreme temperatures, Xinzuo's grass

Table 4
Effects of technological and engineering adaptive measures on grass yields, livestock numbers and livestock income in 2016 in Hulun Buir.

Meteorological disaster affecting factors	Region	County	The changes of grass yield in following year		The changes of livestock number		The changes of livestock income	
Adaptive measures			Technical measures (Breeds improvement)	Engineering measure (Artificial grassland construction)	Technical measures (Breeds improvement)	Engineering measure (Artificial grassland construction)	Technical measures (Breeds improvement)	Engineering measure (Artificial grassland construction)
The extreme temperatures and the drought	Pastoral area	Xinyou	+0.3%	–	+1.7%	–	+7.1%	–
		Xinzuo	+0.2%	–	+0.7%	–	+2.3%	–
		Chen	+0.7%	–	+1.3%	–	+10.7%	–
		Ewenki	+0.8%	+6.4%	+3.5%	+3.4%	+11.7%	+5.7%
	Semi-rural and semi-pastoral area	Zha	+0.2%	+11.7%	+1.5%	+6.5%	+5.7%	+8.3%
		Mo	+0.5%	+8.2%	+1.2%	+5.4%	+4.1%	+7.7%
		Arun	+0.2%	+7.4%	+2.1%	+6.1%	+3.3%	+6.3%

Table 5
Effects of adaptive policies and herders' actions on household income in 2016 in Hulun Buir.

Region	county	Total household income (Dollar)	The changes of household income		Pure income of herders (Dollar)		Non-agricultural income accounts for household income ratio
Adaptive measures		Policy measures (policy subsidy)	Policy measures (policy subsidy)	Herders measures (Non-agricultural labor income)	Policy measures (policy subsidy	Herders measures (Non-agricultural labor income)	Herders measures (Non-agricultural labor income)
Pastoral area	Xinyou	2782	7.30%	2.30%	2593	2652	62%
	Xinzuo	2574	8.10%	1.90%	2381	2856	53%
	Chen	2628	8.30%	4.30%	2426	2336	76%
	Ewenki	2795	8.40%	2.30%	2578	3076	67%
Semi-rural and semi-pastoral area	Zha	3543	15.50%	1.80%	3067	2779	43%
	Mo	2862	8.50%	1.10%	2638	3023	55%
	Arun	3678	16.10%	2.40%	3168	2482	63%

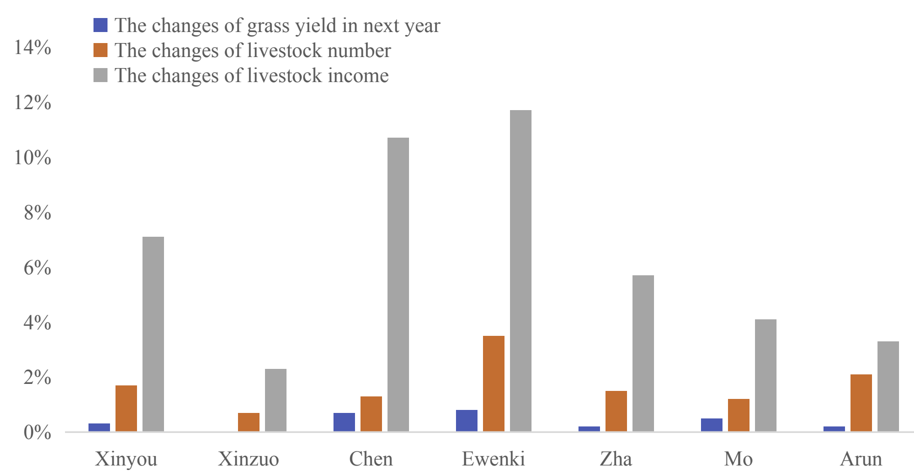

Fig. 2. Effects of livestock breeding improvements under the condition of extreme temperatures on grass yield, livestock numbers and livestock income in 2016 in Hulun Buir.

yield increased by 0.2% in next year with the influence of livestock breeding improvement. The livestock numbers and animal husbandry income increased slightly by 0.7% and 2.3%, which is the smallest change rate among the seven banners, and in Ewenki, although the grass yield increased by only 0.8% in next year, the livestock number and income increased by 3.5% and 11.7% respectively, which showed a notable improvement. In other banners, similarly the livestock breeding improvement had little effect on the grass yield in next year, but it had positive impacts on the livestock number especially on the animal husbandry income.

3.2. *Effects of engineering adaptive measures*

Forage is the basis of animal husbandry. Recently, the insufficient supply of forage caused by grassland degradation seriously restricted the development of local animal husbandry. Artificial grassland is the best choice to figure out the problem and the effect under the influence of drought disasters is shown in Fig. 3.

According to the simulation results, artificial grassland led to a significant increase on the following year's grass production. The largest annual increase of the grass yield in next year was in Zha, reaching 11.7%. The corresponding livestock numbers and animal husbandry income also had a substantial increase of 6.5% and 8.3%,

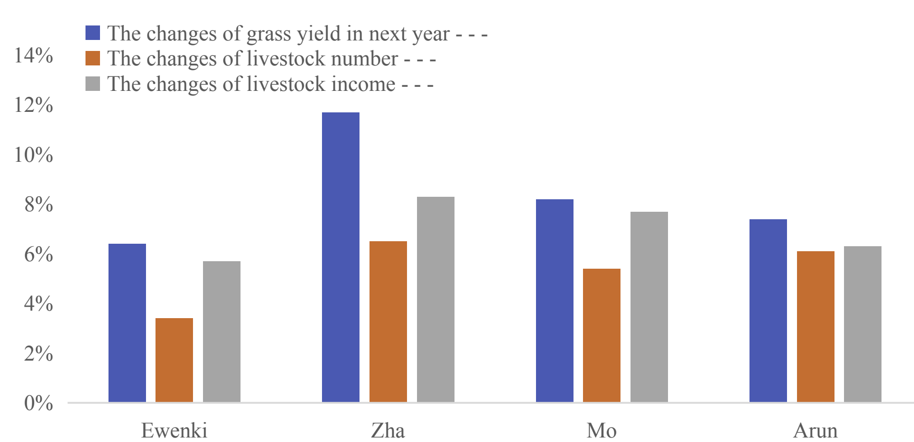

Fig. 3. Effects of artificial grassland under the condition of drought on grass yield, livestock numbers and livestock income in 2016 in Hulun Buir.

respectively. The effects in Mo and Arun were similar. In pastoral area, artificial grassland project only implemented in Ewenki. However, the meaning of artificial grassland is more significant in pastoral than in semi-agricultural and semi-pastoral husbandry area due to the obviously positive impact on raising the quality and strengthening the supplement of forage.

3.3. Effects of adaptive policies

Policies always play an important role in grassland management, since 2010, due to the grassland degradation and ecology damaged, governments had carried out a series policies to protect grassland ecological environment. The effect of adaptive policy subsidies is shown in Fig. 4.

According to the simulation results, policy subsidies can increase herder's income and also had a positive impact on grassland protection. The changes of household income generally increase more than 8%, the biggest increase is in Zha, reaching 15.5%. Both pure income and total household income are reaching 2000 dollars, herders in Arun has the highest overall total household income.

3.4. Effects of the adaptive measures of herders

Due to the grassland protection and extreme weather disasters, some herders supported their family by increasing the proportion of non-agricultural labor income. As the main resource, the income of going out for working is used to calculate the non-agricultural income. The effect of adaptive herders measures is shown in Fig. 5.

The simulation results display that going out for work has a slightly positive impact on the total family income. The changes of household income increased between the range of 1.10% and 4.3%, the rising range is quite slightly. Non-agricultural income accounts at least 43% for household income ratio, even reaching 76% in Chen, occupies a larger portion of total household income.

4. Discussion

The Report of the 19th National Congress pointed out that the main contradiction in Chinese society has been transformed into a contradiction between the people's growing good living needs and unbalanced and inadequate development. One of an outstanding manifestation in this contradiction is that we have not yet been able to fully provide qualified and safe livestock products such as meat, eggs and milk. That is also the key factor restricting the development of local animal husbandry. Doubtless, technology is the core approach to solve this problem and based on the results in Fig. 2, livestock breeding improvement has a great benefit for local animal husbandry. However, livestock is just the basis for animal husbandry development, improving the processing technology and scientific content is the main driving factor to enhance the safety

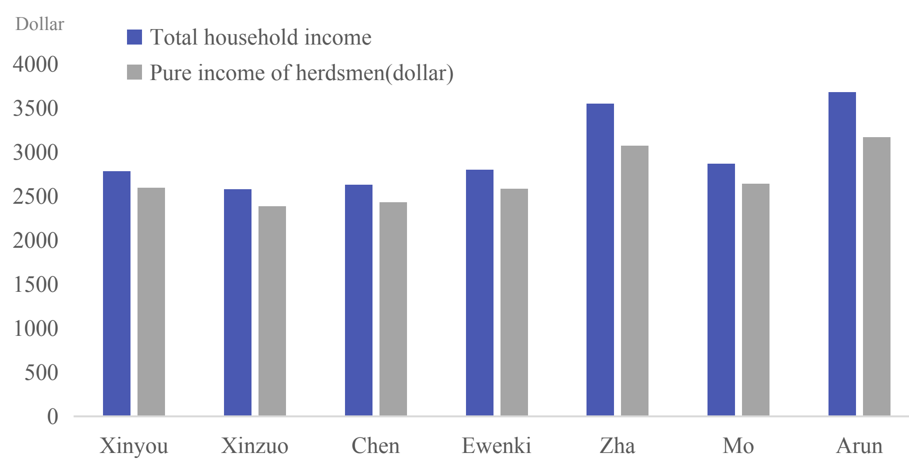

Fig. 4. Effects of policy subsidies on the family income of pastoral households in 2016 in Hulun Buir.

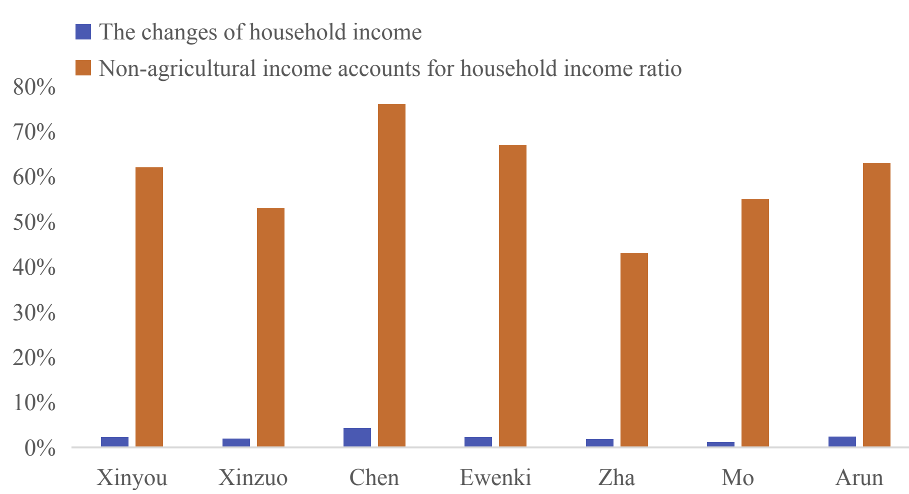

Fig. 5. Effects of farmers' off-farm employment on non-agricultural labor income in 2016 in Hulun Buir.

and quality of livestock products. In addition, creating high quality forage to ensure the nutrition supplement and conservation and increase the efficiency of breeding, especially in the context of grassland degradation resulted from global climate change is also an important approach to improve the quality of livestock products (Capstaff and Miller, 2018). Therefore, developing technological adaptation measures should focusing on improving the livestock breeding, processing technology and high-quality forage.

Additionally, improving the supply capacity of livestock products is not only to meet the needs of the people's dietary structure changes, but also a major strategic need to ensure national food security which requires Chinese's rice bowl should be firmly in our own hands, and filled with Chinese food. Forage and livestock products rely on import heavily is a sever threat to national food security. Artificial grassland project which lead to a great increase in forage supply and restoration in natural grassland can achieve a harmony on the functions between both economic and ecological, is doubtless the most effective method to protect national food security. Fang et al. (2018) constructed the pilot project of artificial grassland in Hunlun Buir region, which can lead to more than 6 times forage supplying compared with nature grassland. However, the proportion of artificial grassland in total area of cultivated land is just 5% at present, much lower than some developed countries with the occupation of 20%–40%, especially in some pastoral where the project has not been implemented, Fang et al. (2018) also pointed that, lacking of technology to improve the quality of grassland breeds is also a threat to national food security. Therefore, developing engineering adaptation measures should expand the construction area of artificial grassland and adjust the structure of the crop industry, increase the proportion of forage crops.

Since 2000, in order to solve the reduction of vegetation coverage and the decline of ecological service functions, the central government has successively implemented a number of ecological protection and construction projects like ‘Returning Grazing Land to Grassland’ and ‘Returning Farmland to Forest’, but the situation of “local improvement and overall deterioration” in the grassland area has not been fundamentally changed (Hoffmann et al., 2016), Li and Li (2015) pointed that series of grazing ban policies has intensified the ecological pressure on the grasslands, in addition, implementation of the series of policies limited grassland grazing, bring on a sever contradiction between ecological protection and animal husbandry which severe restricted local economic development. Therefore, developing adaptive policies should weigh the relationship between grassland protection and economic growth, and realize the harmonious unity of grassland ecology and economic function.

Furthermore, compared with Table 4, we can see the overall level of household income for non-agricultural labor is lower than the income level of families in each county, which reflects that, although non-agricultural labor is a way of adapting to climate change, the herders, especially those living in grassland areas, with low literacy levels or even language barriers, resulting in low pay rates as migrant workers. The disruption to family life caused by the outflow of young workers also affects the harmonious development of society in grassland areas. Therefore, developing the adaptive measures of herders should improve the cultural level and work skills.

5. Conclusion

In this paper, we built a positive mathematical programming (PMP) model to assess the adaptive measures which were divided into four aspects tackling climate change based on the survey data. These findings provide important references for implementing effective adaptive management and promoting sustainable development in grassland.

Technology is the key factor that improved the safety and quality of livestock products. However, technology input should take into account the three aspects of improving livestock breeding, processing technology and high quality forage. Additionally, expanding the scale of animal husbandry production, establishing livestock products brand and enhancing the influence is also an important approach to develop local animal husbandry.

Artificial grassland project is the most effective method to provide high quality and adequate forage. With the changing of people's dietary structure, the proportion of animal husbandry in agriculture is bound to increase significantly which is also an important opportunity of animal husbandry developing. As local pillar industry, developing animal husbandry definitely has a significant positive impact on improving herders' income and promoting local economic growth, it is also complying with the national strategies of ‘Taking Targeted Measures in Poverty Alleviation’ and ‘Rural Revitalization’. Therefore, expanding the scale of artificial grassland construction especially in pastoral area in the context of frequent extreme weather disasters like drought caused by climate change is necessary.

Policy plays a decisive role in grassland management. Protecting grassland ecological environment is although an effective approach tackling climate change, ignoring the economic function of grassland lead to a restrict of herders' income increasing. To realize sustainable development, policies implementing should focus on expanding the scale of animal husbandry production, improving the processing technology and the level of intensification of livestock products, promoting the construction of artificial grassland at the same time of protecting grassland ecology.

The limitation of this paper is lacking of analyzing the intrinsic links of the four adaptive measures, and the integrated effects on tackling climate change and income of herders, which is also the focusing point in the future study.

Conflicts of interest

The authors declare no conflict of interests.

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